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Chapter X

COSTS AND THE SIZE OF PLANTS AND FIRMS

Economic theory designates a limited number of variables upon which the cost of producing an output is held to depend. At the beginning of Part Two (Chapter IV) these were divided into two groups: influences affecting costs for an existing enterprise, and influences operating through a change in plant or firm. The intervening chapters have examined in turn each of the first group of factors, appraising the possibilities and evaluating the techniques for measuring their individual effect. The two cost factors which comprise the second group are considered in this chapter: the relationships between cost and scale of fixed plant and size of firm. In the preceding chapters the assumption of an existing enterprise has served as a measure of economic time; the "short run" is the period in which plant and firm are unchanged, while the "long run" abandons this restriction.[1] This chapter is concerned with a study of the "long run" problem.

1. Preliminary Considerations

The concepts used in the analysis of the relation of costs to size must be clarified and the forces that tend to obscure empirical observation of the relation must be pointed out before one can well examine the factors that cause cost to vary with size.

(a) Failure to distinguish carefully among the problems of size of machine, plant and firm has led to confusion and

[1] See Redvers Opie, "Marshall's Time Analysis," *Economic Journal*, XLI (1931), pp. 199 *et seq.*

inability to arrive at significant results. Obviously a plant, even at the very minimum, is something more than a single machine. Similarly a firm is always more than a plant, even though in some instances the two may be distinguished only by whatever part of his time the owner or executive devotes to buying materials, hiring labor and selling output. It cannot be assumed, moreover, that the lowest cost firm is composed of lowest cost plants, or that lowest cost plants employ lowest cost machines.

A plant is an integration of various fixed factors of production, typically machines, building, production layout, organization, etc. The businessman or engineer who builds or plans new plant must consider the cost-size relations of the various machines in order to determine optimum plant and the variations in average cost attendant on departures from that optimum.[2] The long run cost curve thus drawn for a plant is based on short run curves which assume constant factor prices and homogeneity of the various factors as well as absence of change in the technological possibilities that lie within the horizon of the businessman or his engineers.[3] Such a *ceteris paribus* long run cost curve would seldom be directly relevant to the problems confronting an enterprise, since the prices of input factors for any given output will depend upon the quantity of input factors required for that output. When the *ceteris paribus* long run cost function is thus combined with the directly induced changes in prices of factors, we have a cost function with a more direct relation to business decisions. However, the possible effects of changes in scale of plant on the price received for a unit of output are still ignored. In the remainder of this chapter the term long run cost function, when used without qualification, will describe the relation between cost and size of plant, including directly induced changes in factor prices. The problem of the effect of scale

[2] The complications introduced by desire for flexibility and by additions to existing plant will be considered later in this section.

[3] The relations of short and long run cost curves are considered in more detail below, Section 2.

on the price received per unit of output is not, strictly speaking, part of the subject discussed in this chapter.

A firm represents the integration of two or more economic operations. Each separate operation of a business may, of course, have a different cost-size relation. Thus a manufacturing concern which has marketing and financing functions in addition to numerous lesser activities may have one minimum cost size for production and quite a different minimum cost size judged by the criterion of marketing or financing cost. Hence, the problem as it presents itself in theory to the entrepreneur is to determine the various component cost functions and so to balance them as to achieve the lowest total cost function for each specified demand condition. A partial solution appears to lie in control by one corporation of a number of operating units. Thus a large chain store has retailing, wholesaling, buying, manufacturing, supervisory and financing units of varying size.[4]

The cost-size relation for the firm depends not only on the costs which the firm would incur if it carried on each stage of production, but on costs of purchase in the market. A decision must be made as to whether or not a particular function should be incorporated in the firm or whether the goods or services should be purchased in the market. The criterion is the relative cost of acquiring on the market, all things considered, compared to the cost of producing under the aegis of the firm.[5] This criterion, it will be observed, provides a basis for decision on both balance and vertical integration problems, although it is much more serviceable for the latter type.

The relation between cost and size of firm is frequently given a theoretical statement, but just as the *ceteris paribus*

[4] For a discussion of interest groups (to be distinguished from firms) see Paul M. Sweezy, "Interest Groupings in the American Economy," *The Structure of the American Economy* (National Resources Board, 1939), pp. 306-17. Also see a forthcoming work of R. A. Gordon.

[5] See R. H. Coase, "The Nature of the Firm," *Economica*, IV (NS, November 1937), pp. 387 *et seq*. The author assumes "that the distinguishing mark of the firm is the supersession of the price mechanism."

long run cost function for a plant is only one of the factors relevant to investment decisions, so the present relation provides only one element in the explanation of the size of existing firms. F. H. Knight suggests that "the relation between efficiency and size of firm is one of the most serious problems of theory, being in contrast with the relation for a plant, largely a matter of personality and historical accident rather than of intelligible general principles."[6] For even a partial explanation of the observed sizes of firms, many cost factors other than the cost-size relation would have to be considered. The most fundamental difficulty, however, lies in another direction.

The differences in cost occasioned even by wide variations in size of firm are probably small when compared to cost variations due to historical accident and entrepreneurial ability or to differences in price received for the product attributable to monopoly power. The dynamic force of the individual entrepreneur and the historical accidents that confront his business overshadow the variations in cost resulting from differences in size of firm. Forces outside the framework here outlined tend to overbalance those included. The problem of the most economical size of aggregates of plants is, however, important for public policy. The nature of the problem is such that the only possible approach involves a complex analysis of the economies, buying, financing, supervision, market control, etc., that accompany large scale corporate control.[7]

(b) The study of cost-size relations is widely held to lead to a determination of optimum size. The question immediately arises, optimum for what? The businessman is not primarily interested in lowest cost per unit. Modern economic theory depicts the entrepreneur as seeking to maximize the present value of his future expected earnings. If profits for a period are defined as the difference between

[6] *Risk, Uncertainty and Profit* (London School of Economics and Political Science, 1933), Preface to 2nd ed., p. xxi. What Professor Knight suggests for firms is also true, though in less degree, for plants.

[7] This approach is outlined in Section 2 of this chapter.

the valuations of the streams of earnings expected at the beginning and the close of the period, this statement of the entrepreneur's objective is equivalent to the more familiar proposition that he tries to maximize profits. Under conditions of monopolistic competition, or more broadly, whenever an increase in sales involves a decrease in unit revenue, the size of firm that will yield greatest profits is different from the size that will incur lowest average cost.[8] The empirical investigator of cost-size relations should not expect to find a least cost size in many cases. For when there is not a perfectly elastic demand, there may not be enough firms of the lowest cost size and of larger size to determine with any assurance a least cost size, even if adequate data are at hand. The effect of sloping demand curves on size of plant is not so evident. Insofar as the sloping demand curve really relates to the plant, as in the case of chain stores, there will be so few plants of the least cost size, and *a fortiori* of larger size, that empirical determination of the minimum point of the long run cost function will be impossible. In cases in which the firm rather than the plant faces the demand curve, the tendency to keep plants so small that least cost size is seldom reached or exceeded will not be as strong and more definite results can therefore be expected.

The empirical difficulties just described with respect to least cost size do not, however, detract from the importance of determining the relation of cost to size of firm and plant. The departures from least cost size of observed size and of profit maximizing size raise significant questions concerning full use and optimum allocation of resources, but these problems lie beyond the scope of the present discussion.

(c) The empirical determination of the long run cost function is further complicated because plant is not usually built to produce a constant output either in the short run or over a longer period. Since variations are expected, the entrepreneur is interested in at least three types of flexi-

[8] See E. H. Chamberlin, *The Theory of Monopolistic Competition* (Harvard University Press, 1933), Ch. V.

bility.[9] The first consists of changes such as seasonal variations in output, the familiar weekly cycle of retail store sales, and the daily cycle of passenger transportation, all of which require a type of fixed plant that will be reasonably efficient throughout the range of variation rather than a plant that will have optimal efficiency at any given output. "A plant will often make its boilers, dynamos, vats, or what not, smaller than the most economical size, for the sake of the flexibility that goes with numbers." [10] This sort of flexibility may be built into a firm by differences in the number and type of plants constructed, or built into plant by the use of different sizes and types of machines. An interesting example of flexibility in a firm is found in the balancing of steam and hydro generating plants.[11] Hydro plants have higher fixed costs and lower variable costs than steam plants so that in many localities the hydro plants are lower cost for high load factor demand but more expensive for low load factor demand. Under these conditions it is most economical to have sufficient hydro generating capacity for the base load and to carry the peaks with steam plants. A similar application of the principle of meeting peak demands with low fixed cost equipment is the use of old freight cars to satisfy seasonal demand for increased volumes of transportation.[12] The most common way of obtaining this type of flexibility is by the use of many small identical machines rather than larger units which would be more efficient if regularly fully utilized.

A second type of desirable plant flexibility permits rapid adaptation to long term change in quantity of output demanded. Businessmen are particularly concerned that their plant be easily expanded. It seems obvious that the firm

[9] See Chapter V, above. Also George Stigler, "Production and Distribution in the Short Run," *Journal of Political Economy*, XLVII (June 1939), where the first two types of flexibility are discussed.

[10] J. M. Clark, *Studies in the Economics of Overhead Costs* (University of Chicago Press, 1923), p. 117.

[11] Practical applications of this principle have been pointed out from time to time in electrical engineering journals.

[12] See Appendix C.

which can most economically revise its scale has a competitive advantage; for instance, there is much to be gained from reducing scale in periods of prolonged depression or in secularly declining industries. The efficiency of a plant depends not only on the level of technology prevailing at the time it was built, but on the changes of scale then contemplated.

A third type of flexibility permits economical change to a somewhat different product or an alteration in the proportions of joint or allied products. It is obtained by the use of general purpose rather than entirely specialized machinery. Ford's plant for producing the Model T was an extreme illustration of the absence of this sort of flexibility, and of the reduction in costs that may result when it is sacrificed.

These three types of flexibility have a profound influence on the costs any firm or plant will incur. We must expect empirical study to indicate wide variations in cost among efficient plants or firms of the same size, even when for the moment they are faced with the same type of demand. In particular, there will be found among firms or plants differences in costs which depend on whether the plants were set up all at once, in stages but planned for growth, or haphazardly. Plants larger than the least cost size may be built if the costs for two plants of half the size are greater. Also, when machine units are large compared to size of plant, as in the steel and paper industries, flexibility may require larger plants in order that the various stages of production may be kept in balance when output is changed.

(d) The concern of this chapter is with costs at plant rather than with the competitive position of firms. It would be a mistake to presume that differences in plant costs among enterprises of various sizes adequately represent the variation in their competitive position. A more relevant comparison would be between the costs of placing products in the hands of purchasers in various markets. Competitive position, of course, depends on more than the cost to the firm of making the product and placing it in the purchaser's hands, but such considerations lie beyond the scope of this study. Differences in plant costs by size of firms are not an inaccurate indication of the relative competitive advantages of different sizes of firms.

2. *Factors Influencing the Relation Between Size and Total Costs*

The factors which influence costs as size of *plant* is varied are more or less well defined. It was contended in Section 1 that these forces play a significant role in the determination of plant investment by businessmen. In this section these forces will be examined briefly and then contrasted, in terms of their importance for business decisions, with the forces that determine the relation of cost to size of *firm*. Special attention will be accorded the problems which arise when the relations of cost to size of firm are studied.

If we accept E. A. G. Robinson's *The Structure of Competitive Industry* as a representative modern treatment of the variation of cost with size of enterprise, the forces determining the relation may be considered to fall into five main categories: technical, managerial, financial, marketing, and risk and fluctuation.[13] The forces classified as technical occupy a central position in the usual textbook treatment of the subject.[14] The best known of the technical forces, the division of labor, is conceptually of two types–division into trades which occurred in prehistoric times and has persisted to this day in the crafts, and division into specific operations as on the assembly line of an automobile factory. The latter type of division of labor is intimately bound up with the factory system and has been both a cause and an

[13] Harcourt, Brace (1932), p. 16. The division of technical forces into four types in the next few pages also follows Robinson.

[14] Economic science is indebted to F. Y. Edgeworth for clarification of many of the concepts which are basic to a discussion of the variations of cost elements. See particularly "C: Laws of Increasing and Diminishing Returns" in Edgeworth's *Papers Relating to Political Economy* (Macmillan, London, 1925).

effect of the development of machinery.[15] Adam Smith dwelt on the advantages of this division of tasks in his famous illustration, pin making. The size when the maximum, or at least optimum, division of tasks has been reached is usually rather small and further growth entails mere duplication of the original setup. But, in Robinson's view, since plants typically enter this duplicating stage, other technical forces must be at work. Thus he notes a force which he calls the "Integration of Processes."[16] Here one specialized supermachine replaces a number of teams of persons performing in parallel a series of operations. Many examples are found in the automobile industry: the huge steel press for automobile bodies which replaces a series of processes in the smaller scale operation, or the machine for the Model T Ford, which simultaneously drilled in the cylinder block a number of holes of different sizes from three directions.

A further refinement of the concept of size is necessary at this point, for plants and firms have two dimensions which must be considered in any attempt at measurement. The first dimension may be stated in terms of units of output or any of the other measures suggested below.[17] The second dimension must be expressed in terms of the number of stages of production carried through in the plant or firm. When it is necessary to distinguish these dimensions the first may be called scale and the second depth. The item, "value of products," in the Census of Manufactures is a measure of scale, the item "value added by manufacture" is a measure of the product of scale and depth of any enterprise. As among enterprises producing the same article from different materials the quotients of these Census items would measure roughly the relative depth of the enterprises.

[15] For a good textbook treatment of this subject see F. W. Taussig, *Principles of Economics* (3rd ed., Macmillan, 1921), Ch. 3, especially p. 34.

[16] *Op. cit.*, p. 24.

[17] See Section 3. In the framework of Section 3 only this one dimension is considered, since the assumptions of homogeneous product and constant input factors make the other dimension constant.

It is apparent that the achievement of economies through division of labor and integration of processes depends in large measure upon scale of plant or firm.[18] Robinson points out that possibilities of such integration may lead to an expansion of scale in certain branches of an industry, together with a concomitant lessening of depth of plant or firm. Examples of this tendency are found in the textile finishing industry. Robinson calls this "Vertical Disintegration."[19]

The other economies of scale occasioned by technical forces are common enough in the textbook discussions of the subject: the economy of the large machine and the economy of balance of processes. The former, which has been singled out as a subject for independent study, depends on two factors. First, it is often possible for a man to control a very large machine as easily as he can control a small one when only his initiative and judgment are needed but not his physical strength. Second, in many cases output increases as the cube of some dimension while some cost factor increases only as the square. The reverse of this relation may operate to limit the size of machines. For example, heat losses vary with the area of exposed surface, hence as the square of any dimension, while volume varies as the cube. Blast furnaces, annealing furnaces, etc., have lower heat costs with increases in size; on the other hand, the size of vats in which chemicals are mixed is limited when large amounts of heat are produced because the loss of heat is slower in the larger vats. In Section 4 an example of the relation between size of machine and cost is considered empirically.

The standard textbook treatment of the size of enterprises discovers effective checks on size in certain of the managerial forces. Because important restrictions on size are to be found in this field economists have been prone to underemphasize the importance of managerial forces in promoting large size. Division of labor leads to managerial

[18] Except that an extremely shallow organization may be unable to integrate processes.

[19] *Op. cit.*, p. 25.

economy, although the ultimate difficulty of coordinating the specialists is an important restrictive influence on expansion. Another management economy associated with scale arises from the fact that proportional expansion of most elements of management is unnecessary. On the other hand, restrictive influences are found in the difficulty of coordinating a large management and in the inertia of a bureaucracy, as compared with the rapid action and flexibility possible with a single manager or small management.

The economies and diseconomies of size considered above cut across the distinctions between firm and plant—the term "plant" includes departments concerned with selling, research, etc.—and between scale and depth. If the usefulness of these distinctions is to be preserved, a different system of classification must be used. The forces which cause costs of firm to vary with size may be classified as operating through: (a) scale of plant—quantity of final output of the *plant*, (b) degree of horizontal integration—quantity of final output of the *firm*, (c) depth of plant —number of stages of production in the *plant*, (d) degree of vertical integration among plants—number of stages of production in the *firm*, (e) range of products, (f) geographic spread of plants, and, finally, for want of a more specific term, (g) relative position in the economy. Each of these categories represents a further departure from the model set up at the beginning of Part Two of this report and restated in this chapter.

We should expect simple relationships between cost and any of these factors only when all others are held constant or are allowed for in a satisfactory way by multiple correlation or similar techniques. The relation may be clear and meaningful when two or perhaps even three factors are allowed to vary at once, but when all seven factors are allowed to vary the relation is likely to be too complex to be discoverable empirically. An empirical study of the *ceteris paribus* long run cost function is a study allowing scale of plant (a) alone to vary. In the case of what has been called above the long run cost function for a plant, only (a) and the assembly costs for input factors which are one of the elements grouped under (f) are variable in an empirical study. When a cost comparison of many firms is undertaken the investigator is confronted with data representing the effect on cost of variations in all seven factors, as well as of short run variables. In the remainder of this chapter, the rigorous distinctions among the seven elements of size noted above have been relaxed because of difficulties of measurement. From empirical data one can disentangle meaningful relationships only by the greatest good fortune.[20]

Another approach is through the meticulous analysis of the growth of a single firm. Under favorable conditions it may be possible to remove enough of the extraneous variations to reveal the relation between cost and size of firm. Kurt Ehrke and Erich Schneider attempted to discover such a relationship in their study of a cement mill.[21] The results are not conclusive, but they do indicate that costs decreased with increasing size of firm up to the limit of size attained by the firm. The position of the investigators was singularly favorable, since Ehrke was a member of the firm and thus obtained full access to all records kept by the business. Furthermore, the cement industry is a singularly convenient industry to study because of the relative homogeneity of the product over time. The effect of technical change is difficult to handle and the method (as distinguished from the case) offers no solution to the problem of isolating the relations between cost and the various factors enumerated above.

A more fruitful line of attack would seem to lie in the

[20] In Temporary National Economic Committee, *Monograph No. 13*, "Relative Efficiency of Large, Medium-Sized, and Small Business," the Federal Trade Commission attempts to discover relations under this tangle and even to discover profitability. The results, although interesting, are not reassuring as to the feasibility of such a straightforward attack on the problem.

[21] *Die Übererzeugung in der Zementindustrie, 1858–1913* (G. Fischer, Jena, 1933). Also see Theodor Beste, *Die Optimale Betriebsgrösze als betriebswirtschaftliches Problem* (G. A. Gloeckner, Leipzig, 1933).

investigation of how variations in each of these factors, or in elements associated with them, affect cost. The simplest illustration of the application of this technique occurs in the analysis of how cost of long term borrowing varies with size (factor g). Larger firms are enabled to undertake financing at lower costs, partly as a result of superior bargaining position, and partly because of more complete information, but probably largely because they are better known by the investing public. One of the best studies of the effects on financing costs of such factors as size of issuer, size of issue, etc., is to be found in a report of the Securities and Exchange Commission from which Chart 6 is taken.[22]

The techniques and data for this oblique attack on the problem of least cost size of firm are not yet developed in many of the necessary fields. In one field, however—the relation of size of plant to cost—a great deal of theoretical and empirical work has been done. The remainder of the chapter will deal with the basis and results of this approach.

3. *The Measurement of Cost-Size Relations of Plants*[23]

What are the effects of differences in size of plant upon per unit production cost? Is there a single low area with a wide range of size, or are there several minimum cost sizes, separated by higher cost sizes so that the resulting long run cost curve is a complex function with several minima? Are there significant uniformities between industrial groups?

The theoretical framework of this problem can best be constructed under the usual static assumptions of atomistic competition, homogeneous product, constancy of input

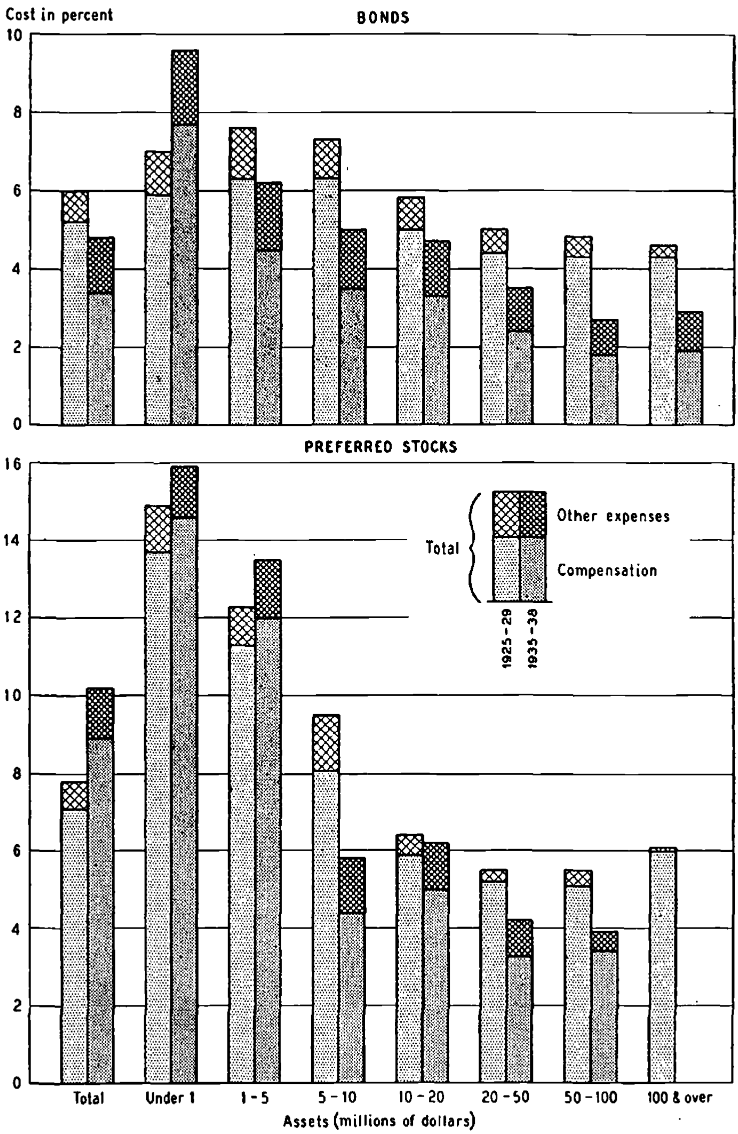
[22] "Cost of Flotation for Small Issues, 1925–1929 and 1935–1938," Report of Research and Statistics Section of the Trading and Exchange Division to the Securities and Exchange Commission (May 1940, mimeographed), facing p. 10.

[23] This section is drawn largely from a memorandum prepared for the Committee by Joel Dean. The distinction between size and scale made above is not relevant to the body of the present discussion because homogeneous product and constancy of input factors are assumed.

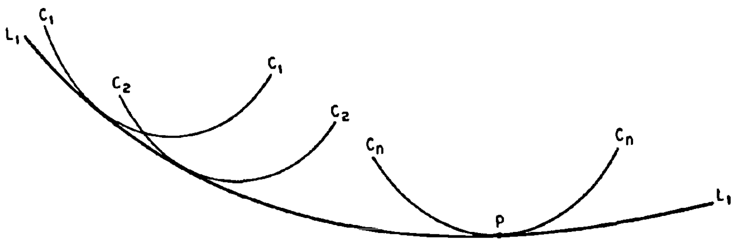
Chart 6

COST OF FLOTATION IN PERCENT OF GROSS PROCEEDS OF ISSUES LESS THAN $5,000,000, 1925-1929 AND 1935-1938

By Size of Issuer



factors and their prices, and stability of the state of the arts. A diagrammatic representation of the hypothetical relationship between cost and scale of plant is shown in the figure below. A number of short run cost curves C_1C_1, C_2C_2, etc., represent different rates of utilization of fixed plants of various sizes.



The envelope of these short run curves represents the *ceteris paribus* long run relationship between average cost and scale of plant L_1L_1. The least cost size of plant is the scale corresponding to the minimum point of this long run cost curve. The point P, therefore, represents the minimum average cost and is also the minimum point of the short run cost curve C_nC_n at this optimum scale. To determine empirically the relationship between cost and scale of plant requires careful consideration of alternative concepts of scale and cost, in order that those which are at once theoretically relevant and empirically measurable may be selected.

To find an appropriate concept of size of plant which will permit practical measurement is not an easy matter. It involves choice among several alternatives:

(1) Amount of fixed equipment
- in physical terms, e.g., number of spindles
- in value terms, e.g., total assets, physical assets, capital assets, tangible net worth

(2) Output capacity
- maximum physical capacity, e.g., noted capacity of blast furnace
- economic capacity, e.g., "efficient" capacity, "normal" capacity

(3) Input capacity
- physical capacity, e.g., size of "charge" of furnace, number of employees or manhours
- economic capacity, e.g., "efficient" capacity, "normal" capacity

If the problem is stated as one of scale of plant, this implies measurement of plant size in terms of fixed factors not readily modified in the short run. The amount of fixed equipment is difficult to measure in physical terms that permit comparison unless the equipment is highly standardized and made up of a large number of homogeneous units. Railroads, for example, might be ordered in size on the basis of trackage or rolling stock, with very different results. Value measures of fixed plant make it possible to summarize and compare heterogeneous physical units, but they involve complex problems of determining the value of plants of varying ages, constructed at different price levels. Hence, measurement of scale of fixed plant by the amount alone is likely to prove unsatisfactory.

Another major alternative is to frame the problem in terms of output capacity of the equipment. Satisfactory measures of output capacity are difficult to find, partly because of lack of homogeneous output units, partly because of difficulty in determining actual capacity. Concepts of physical capacity appear to be inappropriate for this purpose, since the theoretical framework of the problem has been constructed in economic terms. Ideally, economic capacity, in the sense of the minimum point of the short run average cost curve, should be used. There are indications that in some industries physical capacity coincides approximately with economic capacity, for the total cost function is nearly linear over almost the entire range of output, and curves upward only as physical capacity is approached. This means that cost per unit declines over most of the range and reaches a minimum at, or near, the physical limit of the fixed equipment. Under these conditions the problem of measuring economic capacity is simplified.

But not even economic capacity is the theoretically correct concept for determining the long run cost function, for this curve does not pass through the low point of the series of short run cost curves, but is rather the envelope of these curves. Hence what is required is the point of tangency of each curve with the envelope of the entire series. Since it is practically impossible to locate the tangency point empirically, the inevitable discrepancy between theoretical and empirical long run cost functions must be recognized.

The actual observations of cost and output will represent points at various places along the short run cost curve of the individual establishments, rather than the single theoretically desirable point at which the envelope is tangent to the series of short run curves. Consequently, for each output level the statistical observations will lie above the theoretical cost function and will depart from this function by varying amounts, depending upon the shape of the short run curve and the position of the observations on this curve. Moreover, if the observation represents an annual average of several positions on the short run curve, it will necessarily be higher than the minimum point of this curve and probably higher than the envelope of the curve. Nevertheless a curve fitted to these statistical observations may have approximately the same shape as the theoretical function, although it may be higher as well.[24]

Another difference deserves attention. Some theoretical analysis implies that size of plant is a continuous series, whereas actually the series is discrete. Plants do not and cannot form a smooth gradation with respect to size, differing from one another by small and uniform amounts.

[24] Whether or not this is so depends upon whether the position of the observations on the short run curve differs systematically with the scale of output. If, for example, small plants were operated at a higher percentage of capacity than large plants, the functions would differ in shape. It may be that the responsibility for maintaining price will be borne by the firms with larger plants in the industry, allowing firms with smaller plants to shade price. In the absence of counteracting, nonprice competition, this may result in fuller use of small plants.

Instead they form a discrete array with large and irregular differences in size. For this reason the empirical relationship differs inherently from the theoretical continuous curve.

Size can be measured by input capacity as well as by the amount of fixed equipment and the output capacity of this equipment, i.e., by the capacity use of workers or of raw material. Although theoretical analysis is not commonly made in these terms, the same basic discrepancies between theoretical and empirical relationships are involved. There are instances, however (notably when output is so varied that no satisfactory index can be constructed), when an input measure of capacity may prove desirable. Here again it is difficult to find the capacity point along the input scale. If size is measured simply by average input of major raw material over a period of time, it is assumed that all plants have operated at full, or at a uniform proportion of, capacity, and this is not likely to be true. Each study will require consideration of different alternative measures of size. In general, a measure which corresponds most closely to economic capacity would seem most satisfactory.

Recorded cost is affected by many factors other than size of plant. The removal of these variables in order to isolate the effect of size of plant is the central and most difficult problem of methodology. The most important of these irrelevant influences—some of which have been explicitly treated in earlier chapters—are changes in:

(1) rate of output
(2) prices paid for input factors
(3) state of the arts
(4) managerial skill
(5) accounting valuations and procedures
(6) locational advantages
(7) character of products

Differences in percentage of production capacity utilized have an important effect upon cost per unit through the spreading of fixed factors and through the operation of the law of diminishing returns upon increased application of variable factors. Thus, as indicated earlier, the position of a cost observation on the short run cost curve for a particular scale of plant obscures the relationship between scale and cost. Two methods of removing this irrelevant variation are: first, to introduce percentage of utilization as an independent variable in a multiple correlation analysis; and second, to use "normal" or standard burden rates.

Technical advance is likely to becloud the effects of change in size of plant because plants constructed at different dates along the growth curve of successful enterprises are likely to be associated with differences in the state of the arts. Moreover, as the firm grows it may obtain more competent technical advice. Hence the expanded plant is likely to embody more advanced technology, and size and technical progress may be inextricably intertwined.

A fairly clear theoretical distinction between these two factors may be made. At a given level of technology or state of the arts differences will exist between the various sizes of plant in respect to the type of machinery, the size of machines, and the organization of production; but these differences will be associated only with the scale of plant and will involve no technical improvements that were unknown when the smaller plant was designed.

This theoretical distinction is difficult to make in practice, because even when plants of various sizes are built at the same time, cultural lag and ignorance of the best current technical processes will result in variations in technology that are not solely attributable to differences in size. Furthermore, the science of plant design and of production organization and management is not exact. Hence a wide range of differences in technology may exist because of differences in opinion. Despite these difficulties, these two forces must be disentangled if the relationship between cost and size of plant is to be determined.[25]

Differences in accounting valuation and in accounting

[25] An empirical study of the relation between cost and scale might be made by analysis of a group of new plants constructed at about the same time.

procedures are likely to affect average cost as reported in the records of the several firms, and thus to obscure the true relationship between cost and size of plant. Two plants of identical size and technology may have been constructed at the same time under different types of promotion which may lead to the overvaluation of one plant on the books and thus result in higher recorded average cost. Furthermore, the way in which overhead is allocated to production may have considerable effect upon reported average cost. Differences in prices paid for plant and equipment may be considerable if they have been purchased at different times, under different solvency conditions, or in different regions. Removal of these distorting influences constitutes one of the more important research problems.

Differences in the prices paid for input factors, i.e., labor and materials, may tend to conceal the cost-price relationship. Geographic and chronological differences in wage rates and material prices, to the extent that these differences are not a function of the size of the firm (i.e., are not economies of large scale buying), should be removed from the data.

Differences in managerial skill may cause some distortion of the observed relationship between cost and size of plant, for a superior management may, to a degree, equalize the differential advantages of size.

Differential locational advantages not fully compensated by rent differences further complicate cost comparisons. Department store operating costs, for example, appear to be lower in small cities than in large. For this reason crude comparisons which fail to take account of differences in location are misleading.

Differences in products constitute one of the most serious obstacles to collection of suitable data on this point. The number of industries in which plants of varying size make the same product or comparable products in the same proportions is limited.

Four methods of approach to the study of the problem of cost and size of plant merit consideration.

(1) Analysis of changes in actual cost which accompanied the growth of a single plant over a period of time
(2) Analysis of differences in actual cost of plants of different sizes observed at the same time
(3) Analysis of differences in the actual costs of different sized plants operated by one corporation
(4) Engineering estimates of the alternative cost where the same technology of manufacturing is used in plants of different sizes

The first approach encounters what are perhaps insuperable difficulties in the way of correcting the data for changes in products, technology and management, unless the firm displays very little technical advance during its growth. Problems of rectifying cost data for changes in prices, and for differences in valuation and in accounting procedures also arise. Such a project requires complete information about one establishment over a period of continuous and substantial growth, and this is obtainable only by the closest cooperation with the enterprise.[26]

The second approach is more promising. It may be possible in a few industries to select establishments that differ in size but are acceptably similar with respect to other causes of cost variation. Even for the best samples, however, problems of differences in products, techniques of production, construction costs, valuation, price levels and managerial effectiveness will be serious.

Several sources of data should be explored. In some industries, associations like the United Typothetae, the Tanners' Council, the Knitting Machine Institute, and the National Association of Hosiery Manufacturers gather detailed information pertaining to cost, volume and capacity. Other associations might be willing to cooperate with the research agencies in collecting similar data for the special purpose of a study of cost and size, although the availability of data from such sources is questionable.

Again, it might be possible to obtain information directly

[26] See, above, the application of this technique to the problem of costs and size of firm.

from the individual firms in an industry, without working through the trade association. This procedure, however, would prove costly and might not be accorded the full cooperation of the firms covered. The National Research Project of the Work Projects Administration and the National Bureau of Economic Research gathered intimate cost and volume data for a large number of concerns in a few sample industries which had particularly homogeneous products. These data would doubtless be made available for research under proper sponsorship, and the experience and methods employed in collecting the information would be valuable if new data were to be obtained directly from individual firms.

Investigations of the Federal Trade Commission also have required collection of cost data for individual firms. Some of this information has been made public and a large amount of additional data remains in the files of the Commission, where it might be made available for this kind of study.[27] The cost studies of the Tariff Commission, which do not show data for individual enterprises, could perhaps be explored through special tabulations. Similarly, the detailed cost information collected during the National Recovery Administration for the bituminous coal industry is released only in the form of averages for groups of mines. Here too it is probable that records for individual mines, which would permit study of the relationship between cost and size of mine, could be obtained. The difficulties, however, are numerous. The commodity, which is apparently homogeneous, actually differs significantly from mine to mine. Furthermore, costs vary both geographically and with the position and character of the coal seam. Theoretically such differences are equated by rent cost. Yet it may be that those differences in cost that are attributable to size may also be equated and removed by this rent differential. Furthermore, there is wide range of variation in technology, wage rates and valuation.

[27] Temporary National Economic Committee, *Monograph No. 13*, cited above, is largely based on these data.

The Securities and Exchange Commission has for seven years gathered records of individual enterprises listed on the stock exchange. The sample is restricted to large firms and the cost data are not exactly the type desired. Nevertheless, this material deserves close examination. Several summaries of these data have been prepared by WPA projects. Willard Thorp's Census monograph dealing with trends in size of firms has been brought up to date by a WPA project. The Census of Distribution provides rough classifications of various types of distributing firms by size. The retail inventory prepared by Dun and Bradstreet shows more complete cost information but is based on too small a sample. Studies of the operating results of various types of distributing organizations by the Harvard Business School present various size classifications and give cost information in great detail.

Analysis of the data provided by the *Statistics of Income* holds some promise. The groupings, however, are likely to be too broad and the relationship between operating cost and net profit may turn out too equivocal. W. L. Crum's analysis of these data in his *Corporate Size and Earning Power*[28] probably achieves as much as is possible along these lines. The *Census of Electrical Industries* and the Public Utility Commissions provide information concerning size, capacity and operating costs of various types of public utilities. Similarly, the Interstate Commerce Commission collects detailed operating results for railroads. The Census of Manufactures does not give as complete information as might be desired, since its results appear only in the form of group averages. However, special tabulations could be obtained which would deal with more restricted industry groups and classify firms according to size. Some of the difficulties inherent in the use of these types of data will be mentioned and illustrated below.

In view of the numerous problems encountered in the comparison of plants of different ownership, the relationship between cost and size may be examined most easily by

[28] Harvard University Press, 1939.

study of individual units of multiple plant firms. Greater homogeneity with respect to products, accounting methods, valuation basis, technology and management is to be expected when several units are operated under a single ownership. Frequently, however, when a large firm makes a variety of products in several plants, each plant specializes in one group of products and cost comparisons become particularly difficult. Nevertheless, cases may be found in which isolation of cost-size relationships is much easier than for individually owned units.

This approach is not entirely satisfactory, however, since the units of a multiple plant organization are not only somewhat dissimilar under the best conditions but also not completely autonomous. To the extent that administrative functions are performed centrally, the costs of these activities must be omitted from analysis unless they can be satisfactorily allocated to the operating units. Furthermore, differences in managerial effectiveness, although likely to be lessened, are not entirely eliminated. In addition, if the services performed by the central organization are not proportional to the size of the constituent plants, the shape of the cost function will be different from that of independent organizations. Finally, the relationships of cost to price will, of course, be entirely different.

Some of the irrelevant variations due to differences in operating conditions can be removed by careful selection of the sample, rectification of data, cross-classification, and introduction of the source of variation as an independent variable. For example, one could select chain stores that are similar with respect to locality, maturity, and product proportions. By classifying stores according to nonquantitative characteristics such as supervisors, and introducing as independent variables measurable characteristics such as size of city, rate of stock turn, etc., the effect of store size on operating cost might be isolated and measured.

In canvassing sources of information consideration should be given to large, multiple unit firms whose product or service is fairly homogeneous. Oil refiners, brick, cement, flour and bread manufacturers, finance companies and chain stores are rather promising in this respect.

The difficulties encountered when one attempts to hold constant such influences as differences in technology, managerial efficiency, locational advantages, price levels and so forth, enhance the advantages, for the study of cost-size relationships, of engineering estimates of the alternative cost of plants of different sizes employing the same technology. Estimates of this type are frequently made when construction of a new plant is contemplated. The range of size, however, is likely to be narrow and the availability of such data is extremely problematical. Engineering firms regard the information not only as confidential but indeed as part of their stock in trade. Similarly, the manufacturer for whom the estimates are made is not likely to wish to release them unless they are out of date. There is always a question, moreover, as to how adequately such estimates take account of all operating circumstances that cause cost to vary with size of plant.

4. *Empirical Studies of Size and Cost*

The present section is intended to illustrate the types of empirical study that can be made of the relation between size of machine or plant and cost. The final section will present an evaluation of such studies together with suggestions for research.

(A) The first inquiry concerns size of machine and cost. The costs as shown by the accounting records for 31 machines producing book paper were obtained from a comparative study of several firms in July 1936 by the American Paper and Pulp Association. The problems encountered are the measurement of size and the reduction of costs in the different firms to a comparable basis. The data are presented for each machine arranged according to width and speed classes. Size of machine, however, cannot be indicated adequately by this simple classification; an output measure of size which would take into account not only width and speed but thickness or weight would seem more appropriate. Pounds per operating hour is a measure which, while not unambiguous, does take into account the three dimensions of paper.

The second problem is to obtain comparable measures of cost. An examination of the original data indicated a high degree of accounting heterogeneity, especially in relation to figuring the depreciation element of cost. Certain groups of consecutively numbered machines apparently were operated by the same mill or at least by the same company. If it can be assumed that within these groups accounting techniques were uniform, there appears to be a definite relation in each group between size and cost. Straight lines were fitted to the four scatters although a curve slightly convex to the origin would have given a better fit (see Chart 7). In each case the relationship represented by the straight lines gives a significant fit as measured by the standard error, and in each case the relationship has a negative slope.[29] If the sample of 25 machines is representative of the entire universe of paper machines, there is a definite relationship between the size of a paper machine and the "cost" of turning out a pound of the paper customarily produced on it. It must be remembered, however, that the "cost" involved in this relationship is that determined by the accounting policy of the companies involved.

Considerable care must be exercised in interpreting the results of the regression for book paper machines. The two most serious limitations are: first, in most cases the new machines are larger and faster than the old machines; and second, it seems probable that the more expensive or spe-

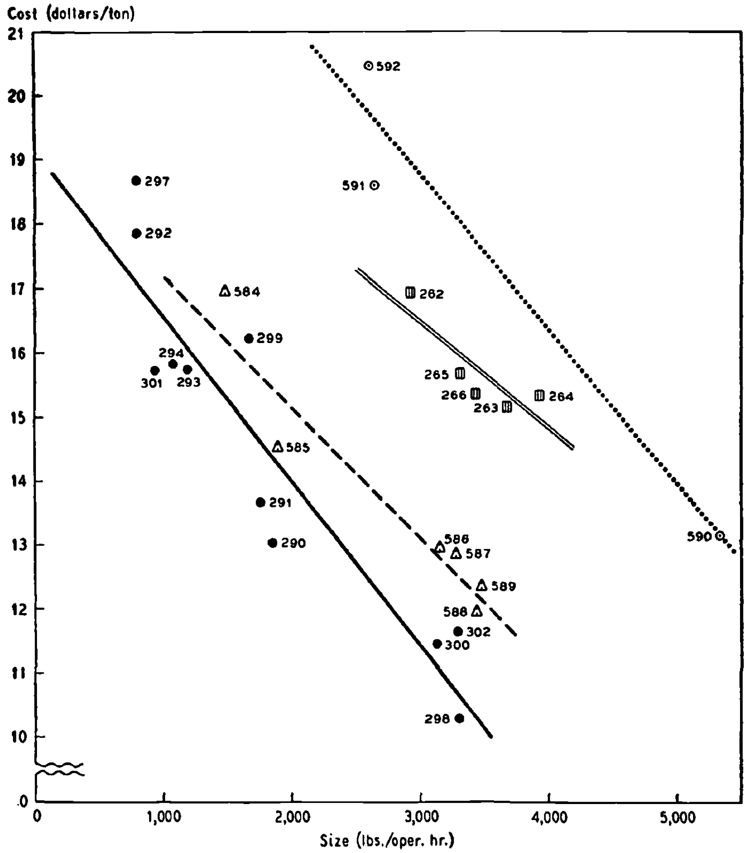
[29] The size of machine was regarded as the independent variable, and lines of the form $y = a + bx$ were fitted. Values of b, and values of r and σ b corrected for number of observations were found as follows:

	b	σ b	r
Case A	−0.2539	0.03325	−0.931
Case B	−0.2053	0.03211	−0.954
Case C	−0.1626	0.05814	−0.850
Case D	−0.2407	0.06534	−0.965
Weighted Average	−0.2224	0.04384	

cialty papers are made on the smaller machines, whereas the cheaper grades are turned out on the largest and fastest machines. It is possible that the entire regression may be explainable in terms of the age of the machines involved.

Chart 7

SIZE AND CONVERSION COSTS OF GROUPED MACHINES IN THE MANUFACTURE OF PAPER



On the other hand, if there is a systematic variation in the type of paper produced on different machines, so that a perfect negative correlation obtains between the unit value of the paper manufactured and the size of the machine, these results show only that it is more costly to produce a pound of high priced paper than a pound of low priced paper. It seems unlikely that either of these factors entirely explains the observed regression, but it is probable that both play a part.

(B) An instance of the use of engineering estimates of cost and size of plant is provided by the following data on petroleum refineries.[30] The estimates refer to the "approximate costs under present conditions of three modern refineries which might be built in three different typical locations"; they were presented to "show how present day refining costs compare with other elements in the cost of finished products at different locations. Of course estimates of this sort can only be made by making numerous assumptions, but the effort has been to approximate the actual possibilities as of June 1, 1939 in various localities."

As presented (see Table 14), the estimates show increasing cost with increasing size. A cursory examination of the breakdown of costs reveals, however, that this is mostly due to the item "pipe line rate to refinery." This charge is hardly relevant to the cost of production, since either the raw material or the product must be transported for sale in any given market. The apparently higher cost of the Gulf Coast refinery is explained also by a higher price of input factors. In the case of all other cost elements the cost either remains constant or declines as size increases.

(C) The electric generating industry offers an almost perfectly homogeneous and measurable output for study. In the survey for "A Superpower System for the Region between Boston and Washington," "a study of 196 steam-electric plants that use bituminous coal was made to ascertain their performance. These plants were selected from the 400 plants in the superpower zone because full and consistent data were available for each plant."[31] For purposes

[30] Testimony of Robert E. Wilson, president of the Pan American Petroleum and Transport Company, *Hearings before the Temporary National Economic Committee*, Part 15, Petroleum Industry, Section II, pp. 8636-37.

[31] U. S. Geological Survey, *Professional Paper 123* (1921).

TABLE 14

ESTIMATED COSTS AND SIZE OF REFINERY

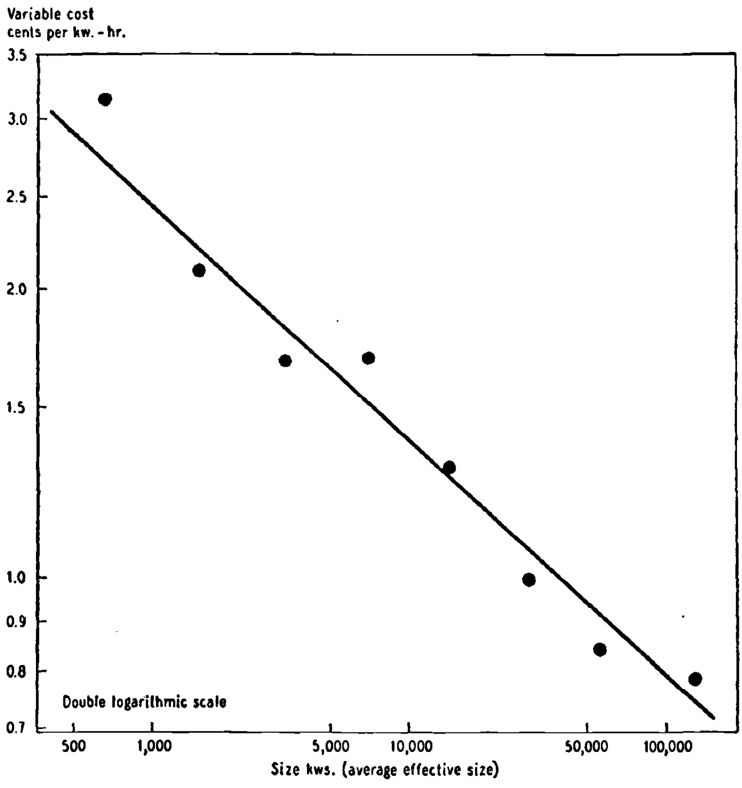
Location of Refinery	*Mid-Continent*	*Gulf Coast*	*Chicago District*
Size of refinery (bbl. crude capacity per calendar day)	5,000	15,000	60,000
Estimated capital investment	$2,000,000	$5,000,000	$16,000,000
Kind of crude run	Mid-Continent	East Texas	Mid-Continent
Gravity of crude (API)	36.0–36.9	38.0–38.9	36.0–36.9
Field price of crude	$1.02	$1.10	$1.02
Gathering charge	.05	.05	.05
Pipe line rate to refinery	..	.125	.345
Direct refinery operating expense (not including fuel)	.16	.11	.08
Taxes, overhead, insurance, etc.	.04	.035	.03
Depreciation (not including obsolescence) at average rate of 7 percent	.077	.064	.051
Miscellaneous charges	.06	.05	.04
Total cost per barrel of crude processed	$1.407	$1.534	$1.616
Total cost per barrel of products	1.529	1.667	1.757

of computation, the cost of coal was taken as $5.35 per ton, the average cost in 1919 for all plants in the superpower zone. The relation between size and variable cost per kilowatt hour for eight size groupings of plants is shown in Chart 8. No account is taken of costs of distribution or of fixed costs.

(D) A great mass of data on costs for size groups is available in the publications of the Census Bureau. In these studies size is almost universally measured in terms of value of sales, while the cost is frequently not given directly, but must be calculated as a percent of sales. The inadequacy of these measures is apparent. The use of Census of Manufactures data will be illustrated by studies of the paint and varnish industry and the manufactured ice industry for 1919 and 1929. The cost of materials, purchased electrical energy, fuel, containers, etc., is the difference between value of products and value added by manufacture. Wages can be approximated by multiplication of the number of wage

Chart 8

VARIABLE COSTS PER KILOWATT HOUR AND SIZE OF GENERATING PLANT



earners by the average wage payment per worker in the industry for the year.[32] The sum of these two items gives direct costs, which in Chart 9 are presented as a percent

[32] This procedure will yield an accurate wage figure only if the average skill is the same in each size group and the average time worked for each employee is the same. On the other hand, it has the advantage of automatically eliminating the effect of differences in wages paid for identical work.

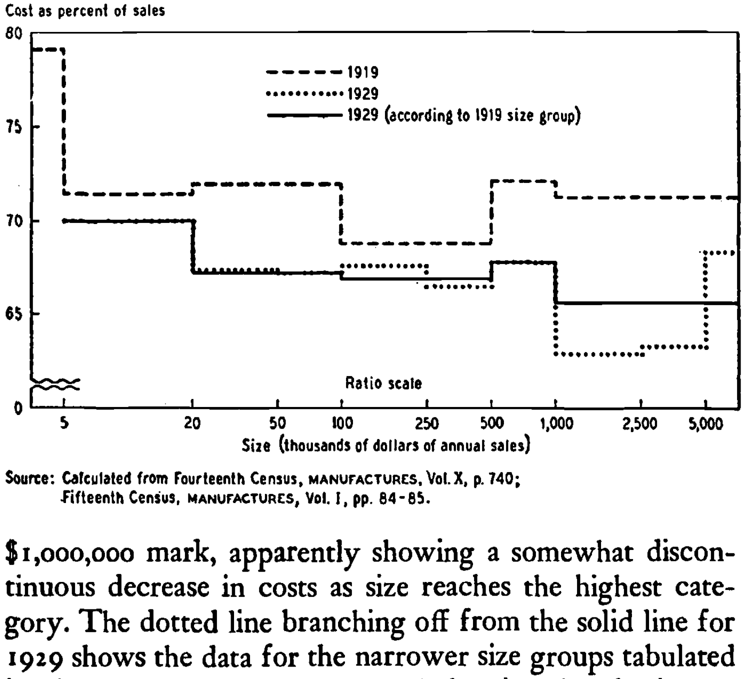
of sales for each size group for the paint and varnish industry.

The shape of the solid and broken line curves of direct costs are strikingly similar. Costs decrease as size mounts up to $500,000 annual output, then rise in the $500,000 to $1,000,000 group and finally fall off again after the

Chart 9

DIRECT COSTS AND SIZE OF PLANT

Paint and Varnish Industry, 1919 and 1929



Source: Calculated from Fourteenth Census, MANUFACTURES, Vol. X, p. 740; Fifteenth Census, MANUFACTURES, Vol. I, pp. 84-85.

$1,000,000 mark, apparently showing a somewhat discontinuous decrease in costs as size reaches the highest category. The dotted line branching off from the solid line for 1929 shows the data for the narrower size groups tabulated in that year. Here costs apparently rise sharply in the largest size class. When the data are as unstable as this, it would be dangerous to try to draw many conclusions.

The ice industry is a better one to study because of its homogeneous product. For 1919 the direct costs decline regularly with increases in size until the largest group is reached, when they rise sharply.[33] In 1929 there is a steady

[33] *Fourteenth Census of the United States* (1919), Vol. X, "Manufactures," p. 959.

decrease over the entire range of size, and with but one minor exception wages and materials costs decline as size increases.[34] The same tendency on the part of wages and materials is observable in the 1919 data, and further examination shows that the high cost of the largest group in that year was caused by an abrupt rise in materials costs. In view of the fact that there are only four firms of large size, it is probably safe to consider the costs of these firms as abnormal and conclude that in the manufactured ice industry cost fell as size increased up to the largest sized plants in operation.

Data for 1933[35] offer a check on the validity of the method of calculating wages paid. Comparison shows that for the size groups arranged in order of number of workers for the whole country the discrepancies between actual and estimated wages are not significant in either the paint and varnish industry or the ice industry; however, for the size groups arranged by size of city the differences between estimated and actual wages in the ice industry are considerable. It is not surprising that the results obtained from a study of these data are not conclusive. Many other factors influencing costs besides size of plant have not been accounted for in this analysis, and no data are available to permit a more detailed analysis.

(E) The Census of Distribution offers data which can be treated more fully. The Fifteenth Census, taken in 1930, in the volume on wholesale distribution presents data on size and cost for various groups of wholesale merchants for the year 1929. As in the case of Census of Manufactures data, the only available measure of output is dollar value of sales, and costs are measured as a percent of this value.

Summary figures for all wholesale merchants classified according to nine size groups (with no distinction according to type of commodity sold) are presented first. There is

[34] *Fifteenth Census of the United States* (1929), Vol. I, "Manufactures," pp. 80-81.

[35] Published in "NRA Statistical Materials No. 43" (mimeographed, Washington, 1936), Table VII and *ibid.*, No. 71, Table XIII.

a steady and regular decrease in cost with increasing size. It would be easy to conclude from this that in wholesaling costs decrease regularly with increasing size. To test this relation, costs for the 21 trade groups were examined. These trade groups, which have a slight degree of homogeneity as to products handled, show only a general downward trend of costs with increasing size. Furthermore, in the 88 trades, which have more homogeneity of products handled, only about 60 percent show this downward trend, and for the 11 most homogeneous trades only 45 percent have the lowest cost in the largest size group. The decreasing proportion of groups showing the lowest cost in the largest size class, as the homogeneity of the groups studied increases, suggests a refutation of the assumption that costs decrease with increasing size.

In order that the problem might be studied under more rigid restrictions, two trades for which data could be obtained by states were examined (in these cases the trade and trade group are synonymous). The costs of wholesalers (exclusive of costs of goods sold) in petroleum and petroleum products decreased fairly regularly throughout the range of observed size from 21.7 percent for those in the class below $25,000 to 13.2 percent for those with sales of over $1,000,000. An examination of the data for individual states, however, shows no such trend. For California, with 86 establishments, costs decrease from 35.7 percent for establishments with sales under $25,000 to 5.2 percent for those with sales between $300,000 and $400,000, and then increase rapidly again to 20.9 percent for those with sales of $1,000,000 or over. For Colorado, with 74 establishments, the lowest cost group again appears in the $300,000 to $400,000 class. Other states, similarly, depart from the pattern shown by the United States as a whole, and the variations are so extreme and so irregular, even when the sample consists of a fairly large number of establishments, that considerable doubt is thrown on the validity of the assumption that the summary series for the United States shows how costs vary with size.

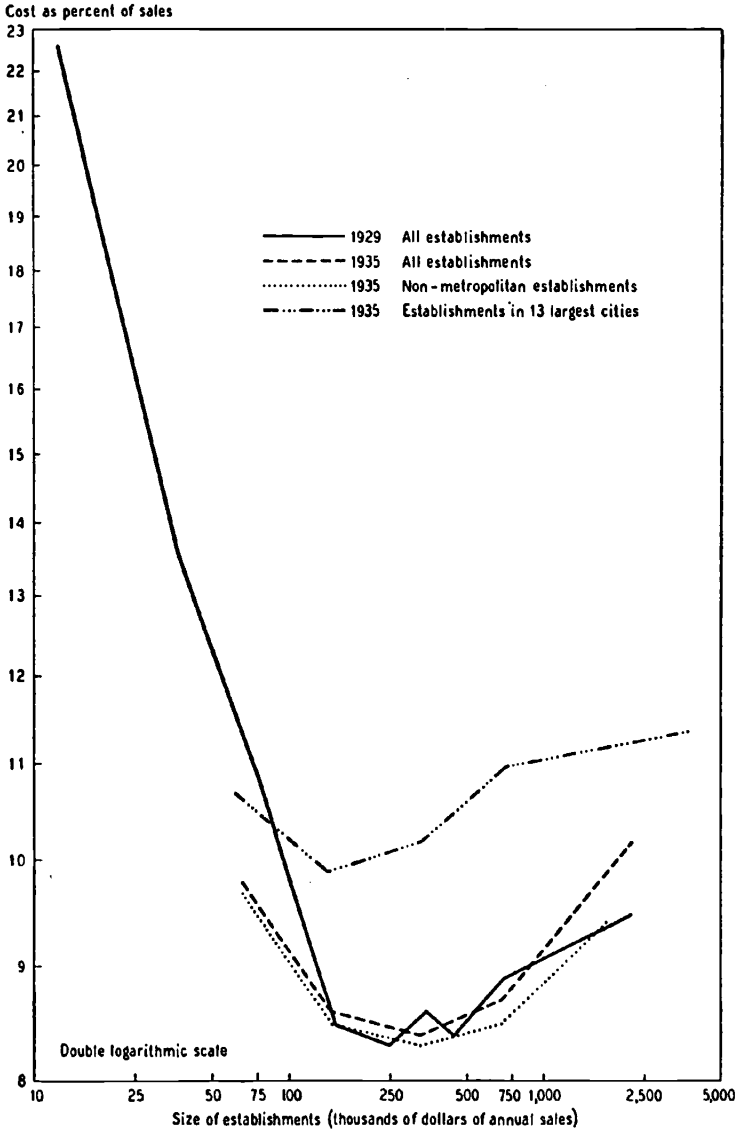
The second trade for which it is possible to secure data by states is the wholesaling of tobacco and tobacco products, which is somewhat more homogeneous than trade in petroleum and petroleum products. A detailed study reveals, however, that 11 large Manhattan merchants, performing apparently an essentially different function, account for an influence on the figures for the whole country which altered the basic pattern of size and cost. When the 11 merchants are omitted, the costs decrease with increasing size for every size group but one. Nevertheless, the figures for the individual states do not exhibit any such marked tendency, although the two largest states, New York and Pennsylvania, show a relatively steady downward relationship in costs. There seems to be a tendency here toward continuously decreasing costs with increasing size.

Finally, in order to obtain a more homogeneous trade with a larger number of establishments, data for the "full-line groceries trade" were utilized from the 1935 Census of Distribution. The breakdowns in this Census show data for 9 geographical regions and for the 13 largest cities of the country. Costs for the United States as a whole for the Census years 1929 and 1935 are shown in Chart 10, as are also costs for the 13 largest cities and for the remainder of the country in 1935. In all these cases the curves are markedly U-shaped. For 8 out of the 9 regions of the country the curve is also U-shaped; and when the establishments in the six cities for which there are complete data are excluded, 8 out of 9 regions show a U-shaped curve, the exception in this case being a different region. It appears probable that costs of doing business as a percentage of sales in the full line grocery wholesaling trade at first drop and then rise with increasing size as measured by dollar volume of sales.

In a number of respects the wholesaling studies are more refined than the studies from the Census of Manufactures. First, the depth of establishments in wholesaling is fairly well circumscribed, although the same is not true in manufacturing. Second, only one variety of wholesaler, the

Chart 10

SIZE OF ESTABLISHMENT AND COST IN FULL-LINE GROCERY WHOLESALING



Calculated from 1929 and 1935 Census of Distribution
Fifteenth Census of U. S., DISTRIBUTION, Vol. II
1935 Census of Business, WHOLESALE DISTRIBUTION, Vol. VI

wholesale merchant, is considered. Third, the effect of size of city can be tested and eliminated by means of separate compilations for the different city sizes as shown in the grocery analysis. Finally, the stability of the relationship can be tested by examination of results for a number of different geographical areas.

The tobacco trade study reveals a long run cost function which decreases rather steadily with increasing size to over $1,000,000 of sales a year. There is some indication, from the case of the 11 Manhattan merchants averaging over $10,000,000 in annual sales, that much larger size entails much higher costs. As has already been noted, however, these firms may not be closely comparable with the other firms. In the grocery trade a U-shaped long run cost function would seem to be quite well established.

(F) Retail trade with its extremely large number of units should offer a fertile field for empirical research in cost-size relations. Unfortunately the data have not been collected and published as abundantly as for wholesaling. Perhaps the most comprehensive collection of material is to be found in Dun and Bradstreet's *Retail Survey*. Here the cities are divided into three size groups: under 20,000 population, 20,000 to 100,000, and over 100,000. In an attempt to discover whether any relationship of cost to size could be shown, thirteen types of stores having the greatest number of representatives in the survey were studied for the two years 1935 and 1936. The results were erratic within each year and were seldom comparable for the two years. No clearly defined pattern emerged. The entire lack of conclusiveness is probably due to both the small size of the sample and the very broad population groupings used.

There are a few more complete studies of cost and size for isolated areas or individual trades. The Bureau of the Census made two such studies in connection with the 1930 Census. One was for drug stores in the Chicago-Milwaukee area (Chart 11). The other study covered combination stores (meat and grocery) in the Louisville-Cincinnati area (Chart 12). The charts showing the behavior of costs and size may be interpreted in several ways, but in general the pattern shows declining costs with increased size until the largest size classification is reached, at which point higher costs are sometimes found.

For a number of years the *Hardware Retailer* has made a study of hardware store costs—perhaps the best single study of its kind. The population groups are fine enough to give a high degree of homogeneity to the type of city except in the case of the largest size group. The hardware study in 1937 showed a regular and steady decline in costs with increases in size for all city size groups except the largest. The discontinuity in the largest group may well be explained by the size of the group in question. We may conclude that in most cases there is a decrease in costs with increasing size of business in hardware stores.

Classification of stores by size of city and by similarity of type as well as by size should yield rather definite results, especially if the problem of imputed wages can be handled adequately. With the data available at present it would be dangerous to try to draw any conclusion other than that costs decrease with size up to a size considerably larger than the average. It would be particularly valuable to apply a correlation technique to retailing data, with special attention to the possibility of fitting a step function.

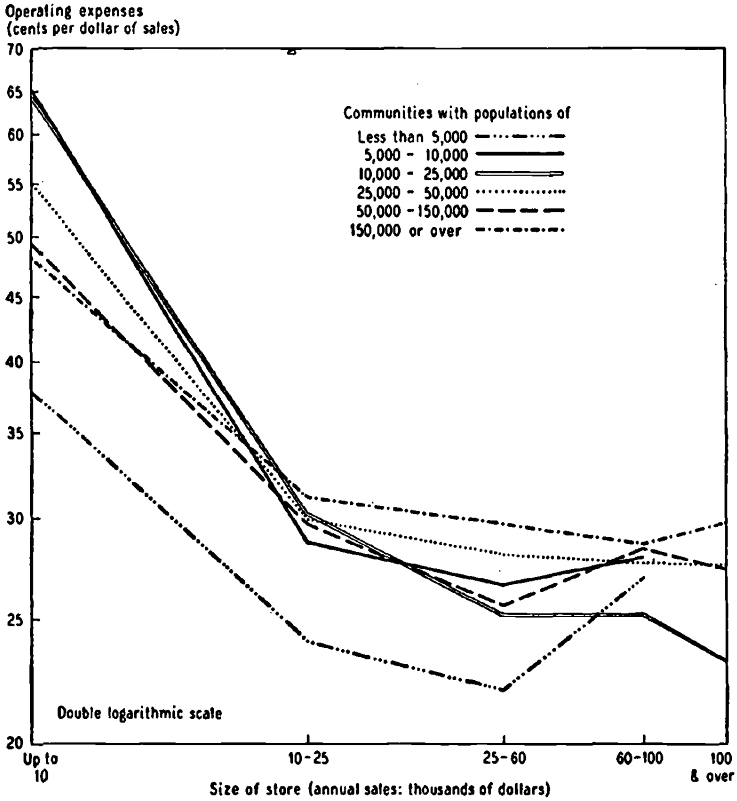
(G) A great many studies of the production of various crops have been made by the State Agricultural Experiment Stations and by the Bureau of Agricultural Economics.[36] A conspicuous difference between these studies and those of manufacturing industries is that the standard criterion of "efficiency" is the income the farmer receives for his labor and management services rather than the cost per unit of the goods produced. Fortunately in many studies the unit cost of production is given or can be derived from other data.

[36] The theory of input-output relations and cost of production studies were treated in *Bulletin 1277* of the United States Department of Agriculture by H. R. Tolley, J. D. Black and M. J. B. Ezekiel, "Input as Related to Output in Farm Organization and Cost of Production Studies" (1924).

A study of apple farms by the Maine Agricultural Experiment Station is typical.[37] Two measures of size are used by the investigators. The first, total capital invested, is a very poor measure. The other, total productive man work

Chart 11

SIZE OF ESTABLISHMENT AND COST IN 3053 DRUG STORES IN CHICAGO – MILWAUKEE AREA



units (essentially a scheme for using arbitrary figures to reduce the various farm outputs to a homogeneous unit) is probably a rather good measure for similar farms. The farms in question are all in one county and derive a con-

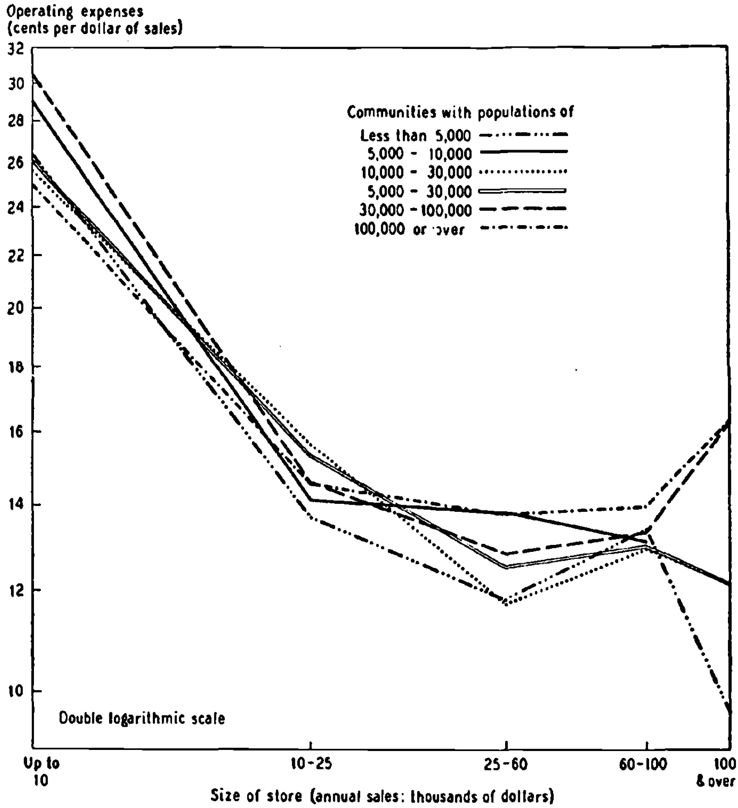
[37] "An Economic Study of 93 Apple Farms in Oxford County, Maine, 1924–1927," *Bulletin 347*, Maine Agricultural Experiment Station (Orono, Maine, October 1928).

siderable part of their income from apples, although the secondary crops are varied.

Three sizes groups are set up: less than 300 p.m.w.u. (productive man work units), 300 to 599 p.m.w.u., and 600

Chart 12

SIZE OF ESTABLISHMENT AND COST IN 2521 COMBINATION STORES (MEAT AND GROCERY) IN LOUISVILLE-CINCINNATI AREA



p.m.w.u. and over. For a three-year period the annual labor income on the 93 farms studied varied with size as follows: small farms $18, medium-sized farms $227, and large farms $484. Although the data for individual farms are not given, it is apparent from other data that there would be a very wide scatter about a regression line for labor income against size of farm business in this apple-growing section.[38] Too many unobserved variables were allowed to influence the results.

A study by the Vermont Agricultural Experiment Station of 138 dairy farms attempts to measure the net effect of size of enterprise on labor income after the effect of other factors has been taken into account. The technique used is a seven-variable multiple and partial correlation analysis. The coefficients of partial and total determination are given in Table 15.

TABLE 15

RELATIVE SIGNIFICANCE OF SIX FACTORS AFFECTING LABOR INCOME[a]

	Factor	*Percentage*
x_1	Total work units per farm	11.2
x_2	Butterfat per cow	14.6
x_3	Yield of hay per acre	1.2
x_4	Man work units per man	21.3
x_5	Percentage of receipts from sources other than livestock	8.3
x_6	Ratio June to November butterfat production	0.9
	TOTAL	57.5

[a] E. W. Bell, "Studies in Vermont Dairy Farming, V. Cabot-Marshfield Area," Vermont Agricultural Experiment Station, *Bulletin 304* (September 1929).

With this procedure it should be possible, by selection of the various factors which make large farms more profitable, to reduce a very high gross correlation between size and income to an insignificant partial correlation. To a certain extent this has happened here. The gross correlation of size of farm (total work units per farm) with labor income is +.49, but the greatest advantage of size of farm is the more efficient use of labor (man work units per man). When the effect of a linear regression between efficiency of labor utilization and labor income has been removed, as well as other variables with a slight correlation with size, the par-

[38] *Ibid.*, p. 136.

tial correlation between size and labor income falls to + .33. A proper statement of the relation revealed by this study is not that variations in size account for 11 percent of the variation in labor income, but that after allowing for a linear regression between efficiency of labor utilization and labor income (this efficiency is largely influenced by size), and for the other four factors which are, with the exception of butterfat per cow, somewhat influenced by size, there still remains 11 percent of the variations in labor income which can be accounted for by a linear regression between size and labor income.

Agricultural investigators have been concerned also with the effect of size on cost in industries that process agricultural products, particularly creameries. The relationship between size and cost is clearly shown by a Minnesota study made in 1920 (Table 16).

TABLE 16

RANGE IN CREAMERY COSTS BY OUTPUT GROUPS[a]

	Costs per Pound of Butter (cents)		
Output Groups	High	Low	Average
Under 100,000	8.1	4.6	5.75
100,000 to 150,000	6.6	3.7	5.05
150,000 to 200,000	5.2	3.5	4.31
200,000 to 250,000	4.6	3.3	4.05
250,000 to 300,000	4.1	3.3	3.77
300,000 to 400,000	3.7	2.8	3.55
400,000 to 500,000	3.4	2.6	3.20
Over 500,000	3.1	2.4	2.98
Average			4.07

[a] "Economic Aspects of Creamery Organization," Minnesota Agricultural Experiment Station, *Technical Bulletin 26* (St. Paul, 1925).

A study of 78 Canadian prairie province creameries gives similar results (Table 17). The analysis by items of cost is particularly interesting in that it shows administration, a factor internal to the organization, increasing in cost after a certain size has been reached.

Such markedly decreasing average costs are theoretically incompatible with a system of pure competition and small units.[39] What, then, are the implications with regard to the observed prevalence of small units and the supposedly com-

TABLE 17

THE RELATION OF VOLUME OF OUTPUT TO COST OF MANUFACTURING A POUND OF BUTTER IN 78 CREAMERIES—PRAIRIE PROVINCES, 1933[a]

(Production per Factory in Thousands of Pounds)

	Less than 100	*100–199*	*200–299*	*300–399*	*400–499*	*500 and More*	*Average*
Number of factories	4	14	22	19	5	14	78
Items of cost in cents							
Plant wages	1.36	1.32	1.05	0.90	0.79	0.76	0.91
Materials and miscellaneous	1.47	1.28	1.28	1.31	1.30	1.18	1.25
Overhead	1.26	0.73	0.66	0.70	0.52	0.48	0.60
Administration	0.73	0.56	0.53	0.71	0.76	0.76	0.69
TOTAL COST	4.82	3.89	3.52	3.62	3.37	3.18	3.45

[a] Department of Agriculture of the Dominion of Canada, *Technical Bulletin 13*, "An Economic Analysis of Creamery Operations in Manitoba, Saskatchewan and Alberta" (Ottawa, March 1938).

petitive nature of agriculture and allied processing industries? In the case of the farms themselves, the small scale is probably influenced by noneconomic factors such as the desire of the farmer to own his own farm and to be his own boss even at the cost of a lower income. In the case of processing or collection plants such as creameries or grain elevators the limit on size is the cost of collection as size increases. Furthermore, sales are in a competitive market[40] while purchases are in either monopsonistic or oligopsonistic markets. This may be why farmers have so often felt the

[39] See especially, J. R. Hicks, *Value and Capital* (Oxford University Press, 1939), Ch. VI.

[40] This is open to some question, but at least the price paid all processors is usually the same or nearly so for the same quality, quantity, etc.

need of setting up their own cooperative monopsonistic or oligopsonistic processor.

A few other studies which are crosses between engineering estimates and empirical research should be noted. The Minnesota Agricultural Experiment Station made a technical study of the possibilities of building different sized creameries and presented cost data based on the findings.[41] Similar data were calculated for local grain elevators.[42] A study undertaken by the New England Research Council attempts to discover the costs of handling milk at country stations of various sizes.

5. *Evaluation of Techniques and Research Possibilities*

From an analytical point of view the most important relationship between size and costs pertains to the firm, summarized in the concept of the long run cost curve. The relationship between size of plant and costs is of secondary significance as an explanation of decisions of the enterprise, although it is much more amenable to statistical approximation. An appraisal of the studies of the preceding section cannot be very enthusiastic about the adequacy of these investigations.[43]

He who attempts to employ the technique of cross-classification of plants in order to remove the effects upon cost of variables other than size is confronted by unpleasant alternatives.[44] If a great many classifications are made, i.e., by size of city, technique utilized and age of enterprise, the

[41] "Judging Creamery Efficiency," *Bulletin 231* (St. Paul, Minn., August 1926).

[42] Hutzel Metzger and H. Bruce Price, "Economic Aspects of Local Elevator Organization," Minnesota Agricultural Experiment Station, *Bulletin 251* (April 1929).

[43] The limitations to the interpretation of any empirical study of size and costs, noted in Section 3, are relevant in this connection.

[44] See Milton Friedman, "The Use of Ranks to Avoid the Assumption of Normality Implicit in the Analysis of Variance," *Journal of the American Statistical Association,* XXXII (December 1937), pp. 675-701.

sample may become too thin for further study or the total effect of "size" may have been removed in the process of cross-classification. "Size" may be correlated in various degrees with these other variables. In fact, it may be impossible to remove the effects of any variable, that is, to improve the homogeneity of the data because its relation to "size" is unknown. Moreover, it cannot be established with any certainty whether the process of classification has ever been carried far enough. What appears to be a relation between size and costs might turn out to be attributable to another variable if classifications were carried further. Several instances of this limitation were evident in the studies summarized in Section 4.

The empirical study of costs in existing plants does not permit a close approximation to the long run cost curve of economic theory. Not only may each plant be producing at some other level on its short run average cost curve than the tangency point with the envelope, but with changes in price in any period it is certain to be out of long run equilibrium. The fact that many establishments have grown piecemeal, and hence may have larger costs for a particular scale than a firm has if planned for that scale, will also distort the statistical relationship out of all resemblance to its analytical counterpart.

Even though these empirical relationships may be poor counterparts for analytical concepts, the relevant issue is whether they are worth while in themselves. The answer to such a question must depend on the purpose at hand and the range of error that can be tolerated. The importance of the relationship between size and costs for public policy as well as for business practice would seem to justify the effort to analyze any information available. Moreover, existing techniques of study can no doubt be improved and other sources of data examined. To this end, the following possibilities for useful research are suggested:

If the original Census data, both for distribution and for manufacturing, were made available for a research project, more refined statistical techniques, such as multiple correlation and confluence analysis, could supplant rather crude cross-classification schemes. Similarly trade association and trade journal data could be more fruitfully analyzed by these more powerful tools.

Again, an inquiry requiring some technical background could delve into the technical changes that have tended to alter the boundary lines of enterprises. This could be either a cross-section study of many industries or a more intensive examination of single enterprises.

There are a number of manufacturing industries, such as shoe fabrication, job printing and hosiery manufacture, for which the investigation of cost-size relationships would appear to offer rather bright possibilities.

Some attempt should be made to apply and utilize the results of studies of the relation between size of plants and costs. It should be possible to estimate in various fields the economies to be achieved by a change in the size of plant. Fairly specific programs of public policy could be formulated in some cases. For instance, given certain value judgments about concentration of economic power, the development of public research in certain industries or the establishment of research activities by trade associations which would pool their resources could be encouraged.

PART THREE

PRICE POLICY